

14.2 ALKENES

Learning outcomes

Candidates should be able to:

1. Recall the reactions (including reagents and conditions) by which alkenes can be produced:
 - (a) Elimination of HX from a halogenoalkane by ethanolic NaOH and heat
 - (b) dehydration of an alcohol, by using a heated catalyst (e.g. Al_2O_3) or a concentrated acid
 - (c) cracking of a longer chain alkane
2. Describe the following reactions of alkenes:
 - (a) The electrophilic addition of
 - (i) hydrogen in a hydrogenation reaction, $H_2(g)$ and Pt/Ni catalyst and heat
 - (ii) steam, $H_2O(g)$ and H_3PO_4 catalyst
 - (iii) a hydrogen halide, $HX(g)$, at room temperature
 - (iv) a halogen, X_2
 - (b) The oxidation by cold dilute acidified $KMnO_4$ to form the diol
 - (c) The oxidation by hot concentrated acidified $KMnO_4$, leading to the rupture of the carbon–carbon double bond and the identities of the subsequent products to determine the position of alkene linkages in larger molecules
 - (d) addition polymerisation exemplified by the reactions of ethene and propene
3. Describe the use of aqueous bromine to show the presence of a C=C bond
4. Describe the mechanism of electrophilic addition in alkenes, using bromine / ethene and hydrogen bromide / propene as examples
5. Describe and explain the inductive effects of alkyl groups on the stability of primary, secondary and tertiary cations formed during electrophilic addition (this should be used to explain Markovnikov addition)

Introduction

Unsaturated hydrocarbons: compounds of hydrogen and carbon only whose molecules contain carbon-to-carbon double bonds (or triple bonds)

1. The molecule of limonene, $C_{10}H_{16}$, contains a 6-membered ring. This is the only cyclic component in its structure.
Which volume of hydrogen, at room conditions, is required to react completely with the C=C double bonds in **one** mole of limonene?

A 12 dm³

B 24 dm³

C 48 dm³

D 72 dm³

2. Substance Q is a hydrocarbon. When 1.00 g of Q is completely burned, 3.22 g of carbon dioxide is produced.
What could be the identity of Q?

A cyclohexene

B cyclopentane

C ethene

D pentane

Preparations

From a halogenoalkanes (dehydrohalogenation - **elimination**)

3. A reaction occurs when a sample of 1-chloropropane is heated under reflux with sodium hydroxide dissolved in ethanol.
Which row is correct?

	type of reaction	name of product
A	elimination	propan-1-ol
B	elimination	propene
C	substitution	propan-1-ol
D	substitution	propene

4. 2-bromopropane reacts with hot ethanolic sodium hydroxide.
Which substance is the major product of this reaction?

A propan-1-ol **B** propan-2-ol **C** 2-hydroxypropene **D** propene

5. Which row describes the solvent used and type of reaction occurring when bromoethane reacts with NaOH to form ethene?

	solvent	type of reaction
A	ethanol	elimination
B	ethanol	substitution
C	water	elimination
D	water	substitution

1. Organic compound **M** forms when 2-bromo-2-methylpropane is heated with **ethanolic** OH⁻.
Draw the structure of **M**.

[1]

2. 2-bromopropane reacts to form propene, hydrogen bromide and water under certain conditions.
(i) Name this type of reaction.

[1]

(ii) Describe the reagents and conditions needed to favour this reaction.

[2]

6. Structural isomerism and stereoisomerism should be considered when answering this question.
2-bromopentane is heated with an excess of ethanolic sodium hydroxide.
How many different hydrocarbons are produced?

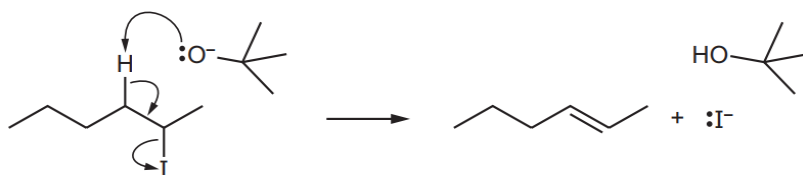
A 1

B 2

C 3

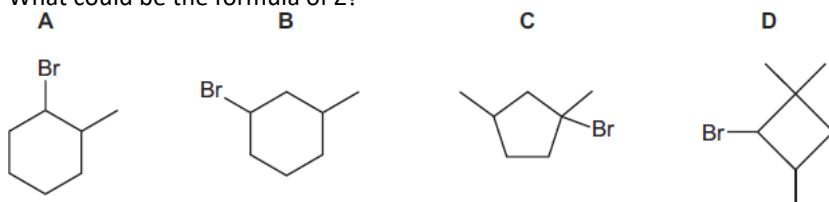
D 4

7. Hex-2-ene can be made by the reaction shown.

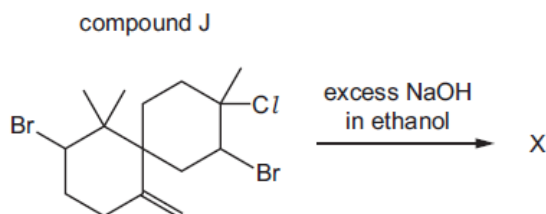


Which statement about this reaction is correct?

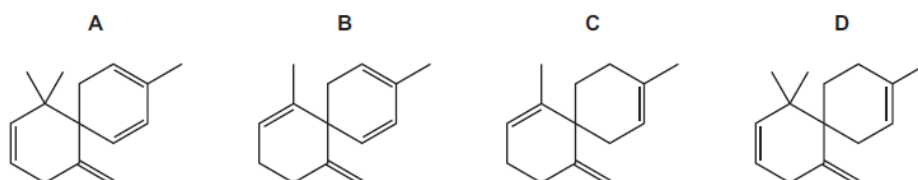
- A** $(\text{CH}_3)_3\text{CO}^-$ is behaving as a Brønsted-Lowry base.
B $(\text{CH}_3)_3\text{CO}^-$ is behaving as an oxidising agent.
C The C-I bond breaks via homolytic fission.
D This is a hydrolysis reaction.
8. Compound Z, $\text{C}_7\text{H}_{13}\text{Br}$, has two chiral centres. A sample of Z contains all four possible optical isomers. This sample of Z reacts with hot ethanolic NaOH to produce a mixture of **only** three isomers. Two of these isomers are optical isomers of each other. What could be the formula of Z?



9. Compound J, $\text{C}_{15}\text{H}_{23}\text{Br}_2\text{Cl}$, is reacted with an excess of a hot concentrated solution of sodium hydroxide in ethanol. One of the products is X.



What could be the skeletal formula of X?



10. Structural isomerism and stereoisomerism should be taken into account when answering this question. How many isomeric alkenes with formula C_5H_8 are present in the mixture produced when 1,4-dibromopentane is reacted with NaOH in ethanol?

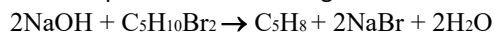
A 1

B 2

C 3

D 4

11. Dibromopentanes can undergo 'double elimination' reactions to produce hydrocarbons.



Which isomer produces only one hydrocarbon product?

- A 1,5-dibromopentane
- B 1,4-dibromopentane
- C 2,3-dibromopentane
- D 2,4-dibromopentane

12. Structural isomerism and stereoisomerism should be considered when answering this question.

A colourless liquid, $\text{C}_5\text{H}_{11}\text{Cl}$, exists as a mixture of two optical isomers.

When heated with sodium hydroxide in ethanol, a mixture of only two alkenes is formed.

What could the colourless liquid be?

- A $(\text{CH}_3\text{CH}_2)_2\text{CHCl}$
- B $\text{CH}_3\text{CH}_2\text{CH}_2\text{CHClCH}_3$
- C $\text{CH}_3\text{CH}_2\text{CCl}(\text{CH}_3)_2$
- D $(\text{CH}_3)_2\text{CHCHClCH}_3$

13. Structural isomerism and stereoisomerism should be considered when answering this question.

2-bromopentane is heated with an excess of ethanolic sodium hydroxide.

How many different hydrocarbons are produced?

A 1

B 2

C 3

D 4

14. A halogenoalkane has the molecular formula $\text{C}_5\text{H}_{11}\text{Br}$. The halogenoalkane does **not** form an alkene when treated with ethanolic sodium hydroxide.

What could be the halogenoalkane?

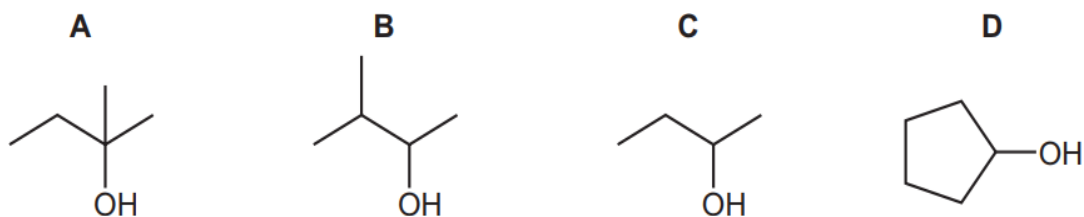
- A 1-bromo-2-methylbutane
- B 2-bromo-2-methylbutane
- C 3-bromopentane
- D 1-bromo-2,2-dimethylpropane

Dehydration of an alcohol

3. A sample of propan-1-ol reacts with concentrated sulfuric acid to form propene. Identify the role of concentrated sulfuric acid in this reaction.

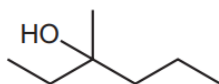
[1]

15. Which compound is a secondary alcohol that can be dehydrated to form an alkene with $M_r = 70$?



16. Structural isomerism and stereoisomerism should be considered when answering this question.
3-methylhexan-3-ol reacts with hot concentrated sulfuric acid to form several isomeric compounds with the molecular formula C_7H_{14} .

3-methylhexan-3-ol



How many isomeric compounds could be formed in this reaction?

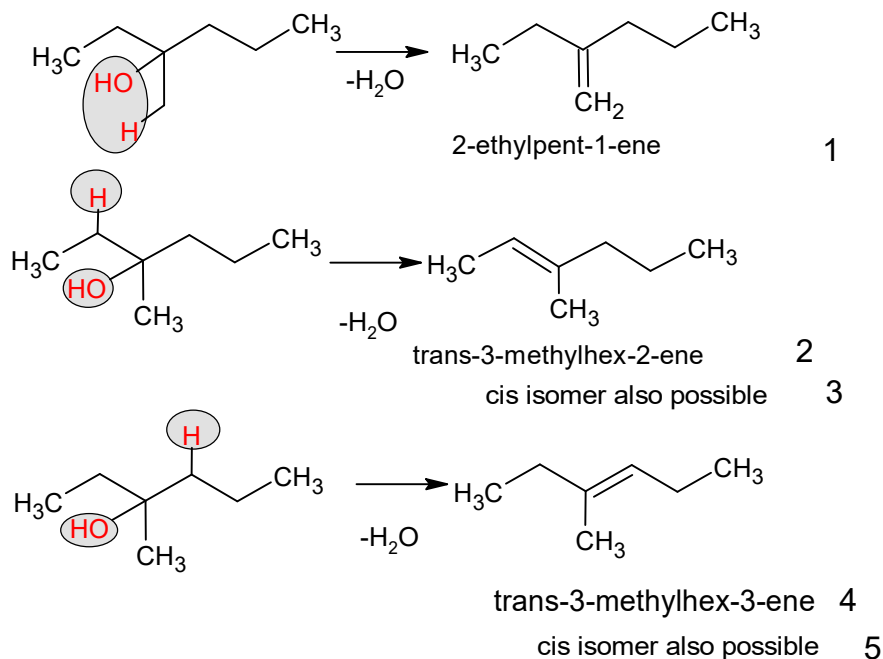
A 3

B 4

C 5

D 6

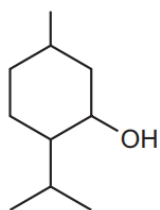
Hint:



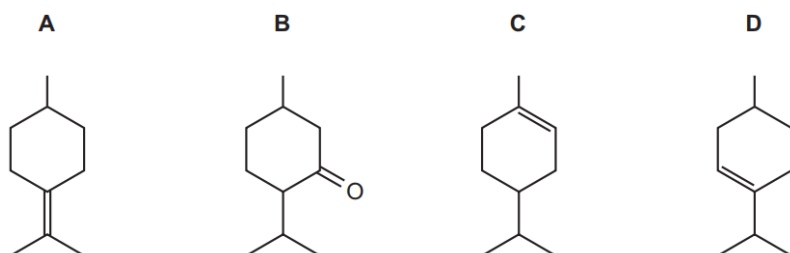
Hence, 5 isomers are possible, and option C is the right answer.

17. Menthol is a naturally occurring alcohol.

menthol



When menthol is heated with concentrated sulfuric acid it reacts. The products formed include compound T. What is the structure of compound T?

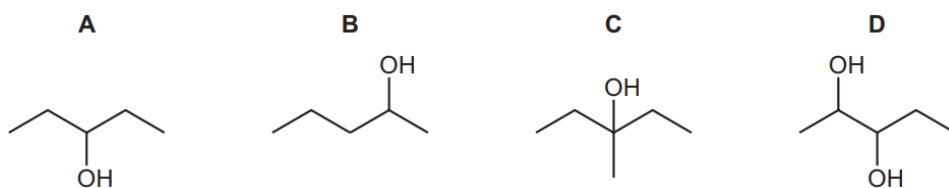


18. Structural and stereoisomerism should be taken into account when answering this question.

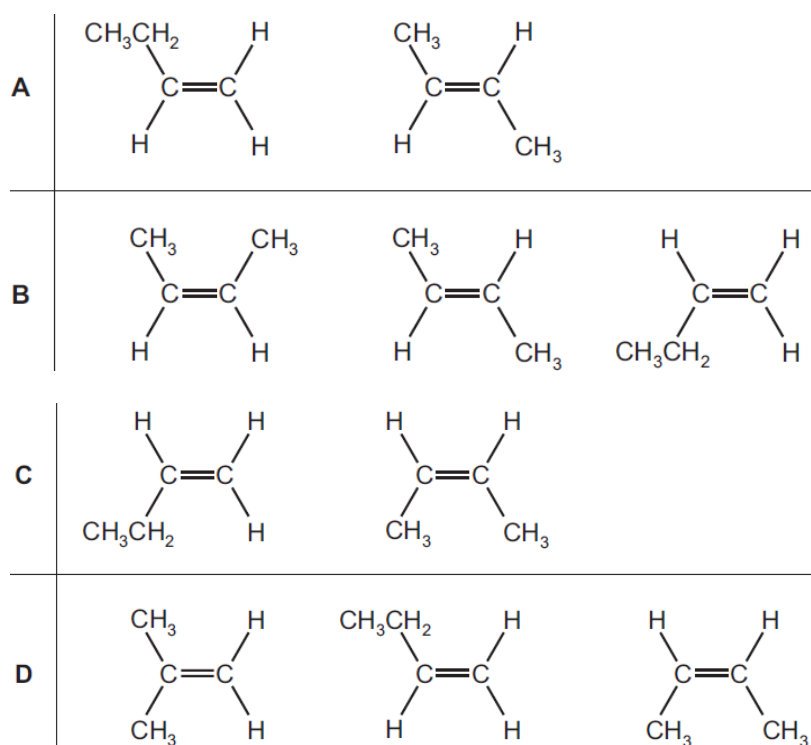
An organic compound, X, is dehydrated by heating with concentrated phosphoric(V) acid.

Only **two** organic products are formed.

What could be X?



19. What are the only structures formed when butan-2-ol is heated with concentrated H₂SO₄?



20. Alcohol X reacts with concentrated sulfuric acid to produce a mixture of products. Two of the products are structural isomers of each other. What could be X?

- A hexan-2-ol
B pentan-1-ol
C pentan-3-ol
D propan-2-ol

Cracking of a longer chain alkane

Cracking: the process in which large, less useful hydrocarbon molecules are broken down into smaller, more useful molecules in oil refinery.

21. Oct-1-ene, $\text{CH}_3(\text{CH}_2)_5\text{CH}=\text{CH}_2$, can be thermally cracked.

Which of the compounds W, X, Y and Z can be obtained by thermally cracking oct-1-ene?

W	X	Y	Z
$\text{CH}_2=\text{CH}_2$	$\text{CH}_3\text{CH}=\text{CH}_2$	$\text{CH}_3\text{CH}_2\text{CH}_3$	$\text{CH}_2=\text{CHCH}=\text{CH}_2$

- A W, X, Y and Z
B W, X and Y only
C W, X and Z only
D W and X only

Properties

Electrophilic addition

The double bond in ethene is formed from a σ (sigma) bond and a π (pi) bond.

There are four electrons in total in this double bond. So, although ethene is a non-polar molecule, there is an area of high electron density around the $\text{C}=\text{C}$ bond. This makes the alkenes open to attack by electrophiles.

An electrophile is an acceptor of a pair of electrons.

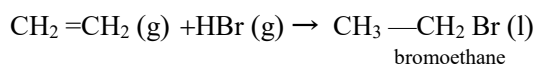
[An Animated Explanation of Electrophilic Addition](#)

Hydrogenation(addition of hydrogen)

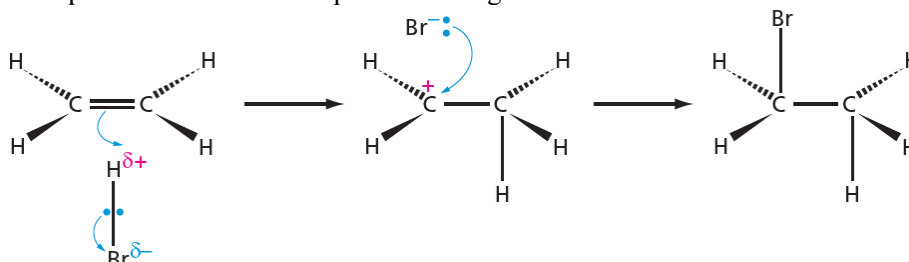
(Studied in preparation of alkanes)

Addition of hydrogen halide

The hydrogen halides HCl , HBr and HI , all react with alkenes to give halogenoalkanes. Either the (gaseous) hydrogen halide is bubbled directly through the alkene, or ethanoic acid is used as a solvent.



The mechanism of this electrophilic addition reaction the electrophile has a permanent dipole. The $\text{H}^{\delta+}$ end of the $\text{H}-\text{Br}$ molecule is attracted to the pi bond in the initial step shown in Figure.



In the mechanism of addition, the H atom acts as the electrophile, accepting a pair of electrons from the $\text{C}=\text{C}$ bond in the alkene.

Inductive effect

Markovnikov's rule states that when HX adds to a double bond:

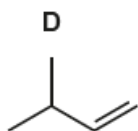
- The hydrogen atom attaches to the carbon that already has the most hydrogens, or
- The electrophile adds in the orientation that produces the most stable intermediate cation.

Where two addition products are possible, the major product is the one that has the halogen atom bonded to the C=C carbon atom with the highest number of alkyl groups bonded to it.

Intermediate: a species such as a carbocation, which is formed at a particular step of the reaction.

Intermediates are stable enough to react with another substance but not stable enough to be products. They often have a partial positive or negative charge.

4. **D** reacts with HBr to produce **F**, a chiral bromoalkane.



Draw the structure of **F**.

22. Two students each make a statement about 2-methylbut-1-ene.

Student 1 states that 2-methylbut-1-ene has geometrical isomers.

Student 2 states that 2-methylbut-1-ene reacts with HBr in an addition reaction to give 1-bromo-2-methylbutane as the main product.

Which students are correct?

- A** both 1 and 2
- B** 1 only
- C** 2 only
- D** neither 1 nor 2

5. **C** reacts with HBr to form **E**.

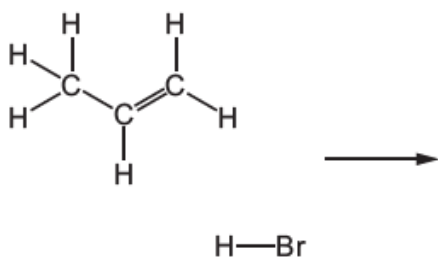
Complete the diagram in Fig. 4.2 to show the mechanism for this reaction.

Draw the structure of the organic intermediate.

Include charges, dipoles, lone pairs of electrons and curly arrows, as appropriate.



6. HBr reacts with propene to form two bromoalkanes, $\text{CH}_3\text{CH}_2\text{CH}_2\text{Br}$ and $(\text{CH}_3)_2\text{CHBr}$.
 (i) Complete the diagram to show the mechanism of the reaction of HBr and propene to form the major organic product.
 Include charges, dipoles, lone pairs of electrons and curly arrows, as appropriate.
 Draw the structures of the intermediate and the major organic product.



- (ii) Explain why the two bromoalkanes are not produced in equal amounts by this reaction.

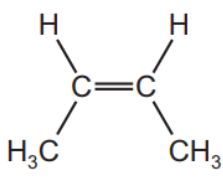
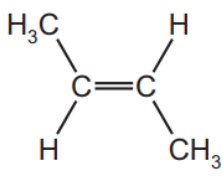
7. 2-methylpropene reacts with HCl(g) at room temperature. The major organic product is 2-chloro-2-methylpropane.
 (i) Complete Fig. 4.1 to show the structure of the intermediate and mechanism for this reaction. Include charges, dipoles, lone pairs of electrons and curly arrows as appropriate. [3]



- (ii) Explain why, in this reaction, 2-chloro-2-methylpropane is produced at a higher yield than 1-chloro-2-methylpropane. [2]

8. **W** is an alkene with formula C_4H_8 . It reacts with HBr to form two possible carbocations, $CH_3C^+(H)(CH_2CH_3)$ and $H_2C^+CH_2CH_2CH_3$.

(i) Identify **W** as compound **A**, **B**, **C** or **D**.

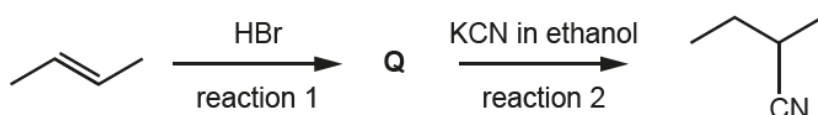
A	$CH_3CH_2CH=CH_2$
B	
C	
D	$CH_2=C(CH_3)_2$

(ii) Draw the skeletal formula of the major organic product formed when HBr reacts with **W**.
Explain why this is the major organic product.

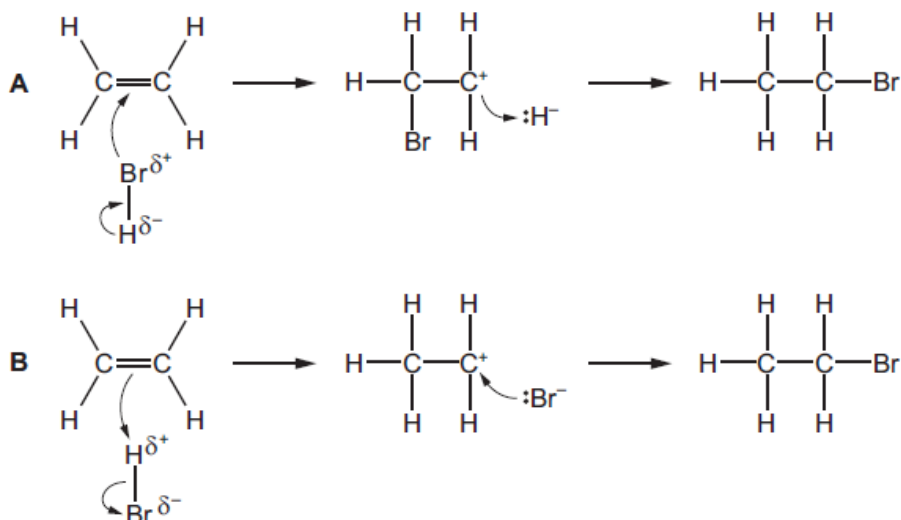
[3]

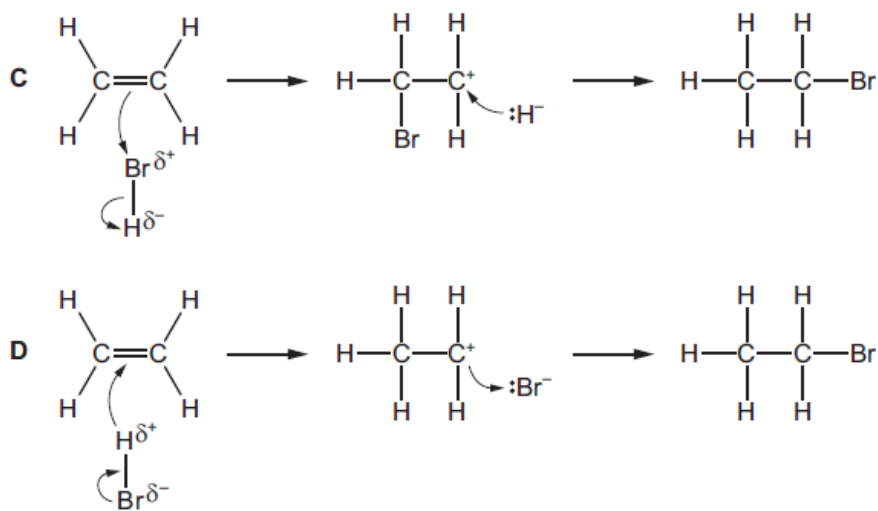
9. Give the structural formula of **Q**.

[1]



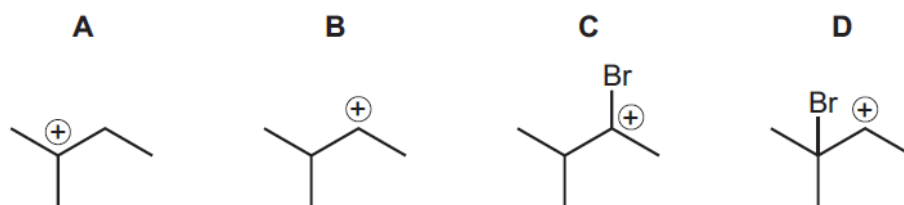
23. What is the correct mechanism for the addition of hydrogen bromide to ethene?





24. 2-methylbut-2-ene reacts with HBr(g) to form two isomeric products. During the reaction two positively charged intermediates can be made.

Which diagram shows the more stable of the two positively charged intermediates?



25. Alkynes are hydrocarbons that contain one triple $\text{C}\equiv\text{C}$ bond.

Like alkenes, alkynes take part in addition reactions. A saturated compound can be formed.

For example, ethyne, $\text{H}-\text{C}\equiv\text{C}-\text{H}$, reacts with excess hydrogen to form ethane.

Propyne, C_3H_4 , undergoes an addition reaction with an excess of hydrogen bromide in two stages.

Markovnikov's rule applies to the addition of HBr at each stage.

What is the main product obtained when propyne reacts with an excess of hydrogen bromide?

- A $\text{CH}_2\text{BrCH}_2\text{CH}_2\text{Br}$
 B $\text{CH}_3\text{CH}_2\text{CHBr}_2$
 C $\text{CH}_3\text{CHBrCH}_2\text{Br}$
 D $\text{CH}_3\text{CBr}_2\text{CH}_3$

26. Alkenes react with aqueous hydrogen bromide. The reaction proceeds via an intermediate carbocation. The more stable the intermediate, the faster the reaction.

Which sequence correctly shows an increase in the speed of reaction of the alkenes with hydrogen bromide?

A ethene, propene, 2-methylpropene

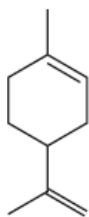
B 2-methylpropene, ethene, propene

C propene, ethene, 2-methylpropene

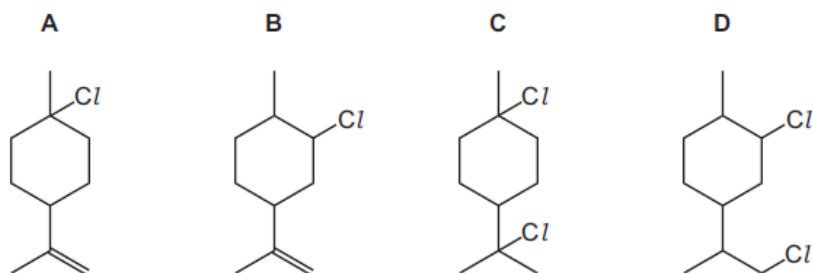
D propene, 2-methylpropene, ethene

27. Limonene is found in lemon and orange oils.

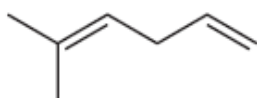
limonene



What is the major product when limonene reacts with an excess of dry hydrogen chloride?



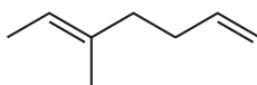
28. The alkene shown reacts with an excess of HBr via an electrophilic addition reaction.



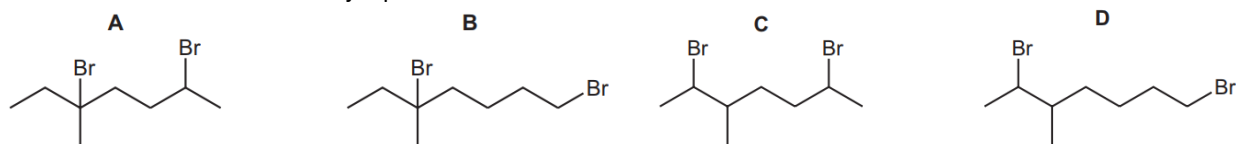
What is the **major** product formed?

- A** 3,5-dibromo-2-methylhexane
B 2,5-dibromo-2-methylhexane
C 2,6-dibromo-2-methylhexane
D 3,6-dibromo-2-methylhexane

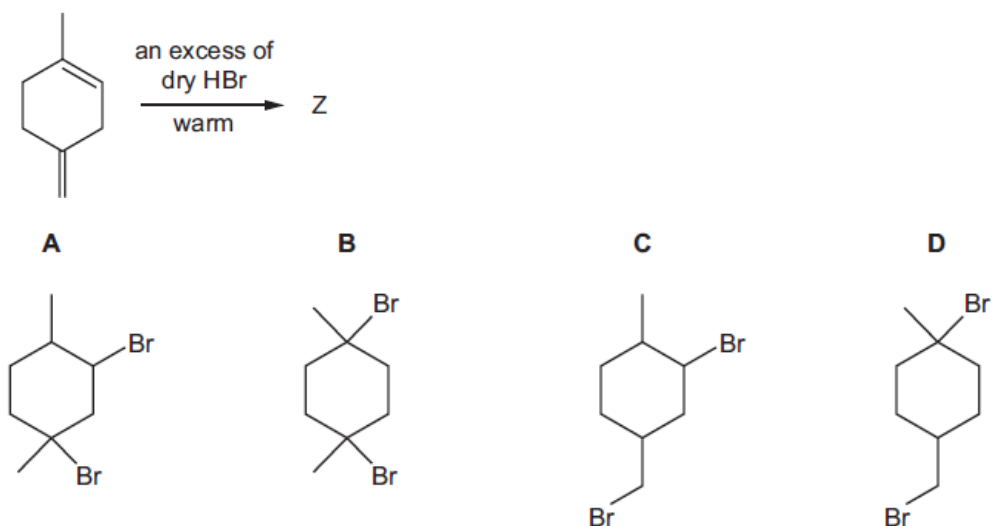
29. The structure of compound X is shown.
compound X



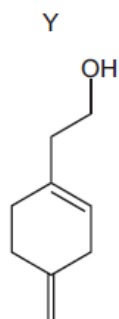
One mole of compound X reacts completely with two moles of hydrogen bromide.
What is the structure of the major product of this reaction?



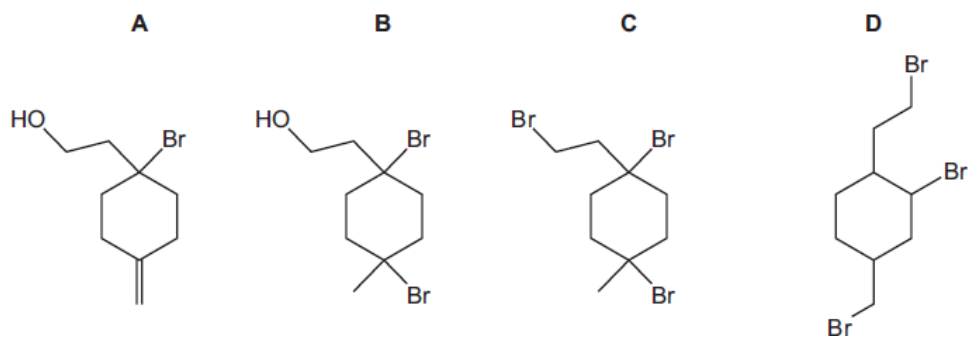
30. What is the major product Z of the following reaction?



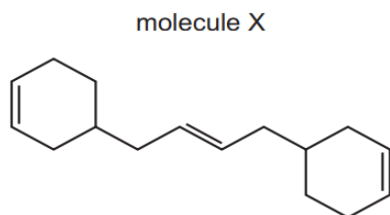
31. An excess of dry HBr is warmed with compound Y.



What is the major product of the reaction?



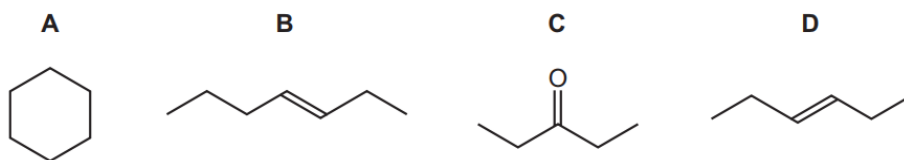
32. Structural isomerism only should be considered when answering this question.
 Molecule X contains three C=C double bonds. One mole of X is reacted with three moles of HBr.
 The carbon skeleton is unchanged.



How many different products are formed?

- A** 3 **B** 4 **C** 6 **D** 8

33. Which compound has an M_r of 84 and will react with HBr to give a product with an M_r of 164.9?



34. Structural and stereoisomerism should be considered when answering this question.
When trans-pent-2-ene reacts with HBr, how many different products can form?

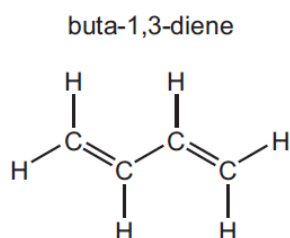
A 1

B 2

C 3

D 4

35. The diagram shows the structure of buta-1,3-diene.



The addition reaction between buta-1,3-diene and two molecules of hydrogen bromide can produce three structurally isomeric products.

How many of these products have at least one chiral centre?

A 0

B 1

C 2

D 3

36. What is the structural formula of the major product when hydrogen bromide reacts with 2-methylbut-2-ene?

A $\text{CH}_2\text{BrCH}(\text{CH}_3)\text{CH}_2\text{CH}_3$

B $(\text{CH}_3)_2\text{CBrCH}_2\text{CH}_3$

C $(\text{CH}_3)_2\text{CHCHBrCH}_3$

D $(\text{CH}_3)_2\text{CHCH}_2\text{CH}_2\text{Br}$

37. Which intermediate ion forms in the greatest amount during the addition of HBr to propene?

A $\text{CH}_3\text{CH}^+\text{CH}_3$

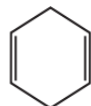
B $\text{CH}_3\text{CH}_2\text{CH}_2^+$

C $\text{CH}_3\text{CH}^-\text{CH}_2\text{Br}$

D $\text{CH}_3\text{CHBrCH}_2^-$

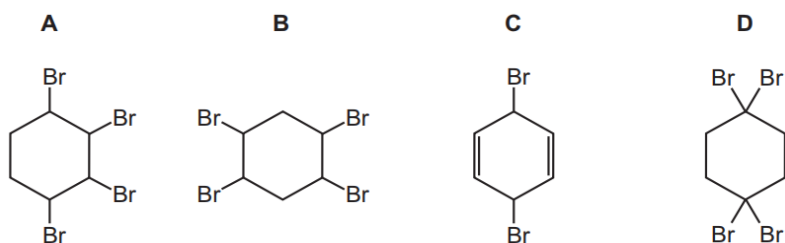
Addition of halogen, X₂

38. Cyclohexa-1,4-diene is treated with a solution of bromine in tetrachloromethane in the dark.



cyclohexa-1,4-diene

Which product is formed?



10. Complete Fig. 4.2 to show the mechanism for the formation of 1,2-dibromoethane in reaction 1. Include charges, dipoles, lone pairs of electrons and curly arrows as appropriate.

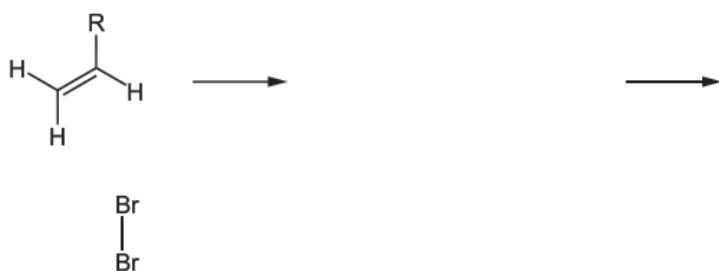
[4]



11. Unsaturated acids are often brominated before being added to soft drinks. Complete the mechanism for the addition of Br₂ to 4-pentenoic acid.

- Include the structures of the intermediate and the product of the reaction.
- Include all charges, partial charges, lone pairs and curly arrows.

In the mechanism, R has been used to represent (CH₂)₂COOH.



[4]

12. Complete the diagram in Fig. 4.5 to show the mechanism for the reaction of propene with Br₂. Include charges, dipoles, lone pairs of electrons and curly arrows, as appropriate.



Fig. 4.5

[3]

39. Bromine reacts with alkenes by an electrophilic addition mechanism in which a cation is formed as an intermediate.

Which mixture will produce the most stable intermediate cation?

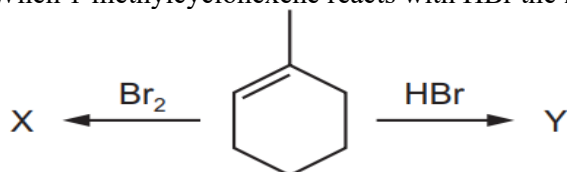
A 3,3-dimethylpent-1-ene + bromine

B ethene + bromine

C methylpropene + bromine

D propene + bromine

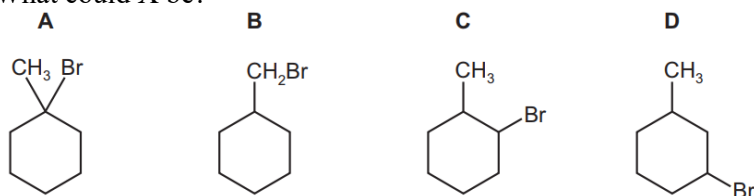
40. When 1-methylcyclohexene reacts with Br₂ the product is X.
When 1-methylcyclohexene reacts with HBr the **major** product is Y.



Which statement is correct?

- A X is a mixture of two stereoisomers; Y does **not** have stereoisomers.
B X is a mixture of two stereoisomers; Y is a mixture of four stereoisomers.
C X is a mixture of four stereoisomers; Y does **not** have stereoisomers.
D X is a mixture of four stereoisomers; Y is a mixture of four stereoisomers.

41. Compound X, C₇H₁₃Br, reacts with hot alcoholic NaOH to produce two compounds, Y and Z.
On reaction with Br₂, Y gives a product, C₇H₁₂Br₂, which exists as a mixture of four optical isomers.
On reaction with Br₂, Z gives a product, C₇H₁₂Br₂, which is non-chiral.
What could X be?



13. Compound V is a liquid.

V contains 77.2% carbon, 11.4% hydrogen and 11.4% oxygen by mass.

V has a relative molecular mass of 280.

(a) Calculate the molecular formula of V. Show your working.

molecular formula of V =

[3]

(b) A 3.196g sample of Br₂ reacts completely with 2.800g of V.

Calculate how many alkene functional groups are present in one molecule of V. Show your working.

number of alkene functional groups in V = [1]

42. Structural isomerism and stereoisomerism should be considered when answering this question.

A set of isomeric hydrocarbons:

- all contain 14.3% by mass of hydrogen
- all react with bromine by addition, 0.280g of each hydrocarbon reacting with 0.799g of bromine.

What is the maximum number of isomeric compounds in the set?

A 1

B 3

C 4

D 5

43. What is the major product when 2-methylpent-2-ene reacts with hydrogen bromide?

- A 1-bromo-2-methylpentane
- B 2-bromo-2-methylpentane
- C 3-bromo-2-methylpentane
- D 4-bromo-2-methylpentane

Use of aqueous bromine to show the presence of a C=C bond



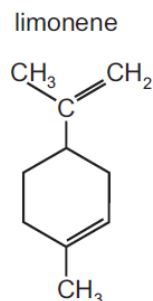
Figure: decolorization of bromine water by unsaturated compound

14. $C_{60}H_{18}$ is an alkene.
(i) State a test to indicate the presence of double bonds between carbon atoms in alkene molecules. [1]
(ii) State the observations seen when the test in (i) is carried out on an alkene. [1]
15. Identify a reagent which could be used to show that **X** contains a C=C. Include relevant observations. [2]
44. When bromoethane reacts with hot ethanolic sodium hydroxide a colourless gas is formed. This gas decolourises aqueous bromine.
What is the colourless gas?
- A** 1,2-dibromoethane
B ethanol
C ethene
D hydrogen bromide
45. Structural isomerism and stereoisomerism should be considered when answering this question.
Y is a gaseous hydrocarbon which decolourises aqueous bromine.
10.0 g of Y occupies a volume of 3.43 dm^3 under room conditions.
How many isomeric structures are possible for Y?

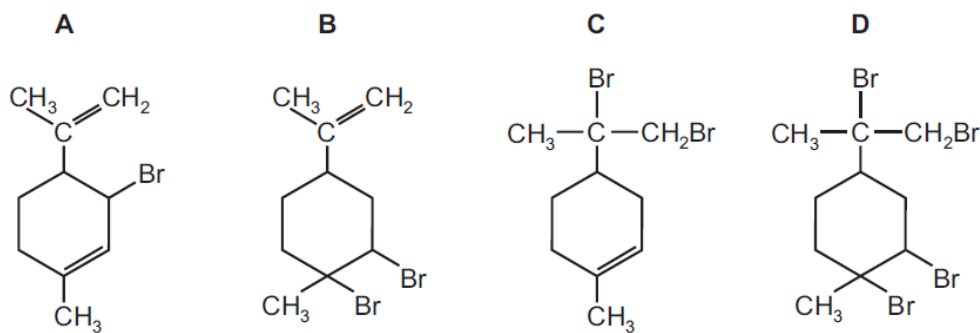
46. Which compound will decolourise Br₂(aq)?

- A CH₃CH₂CH₂CH₂CH₂CO₂H
- B CH₃CH₂CH₂CH₂CH₂CHO
- C CH₃CHCHCH₂CH₂CH₂OH
- D CH₃CH₂CH₂CO₂CH₂CH₃

47. Limonene is an oil formed in the peel of citrus fruits.



Which product is formed when an excess of bromine, Br₂(l), reacts with limonene at room temperature in the dark?



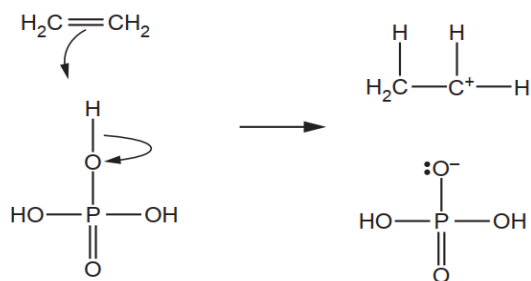
Addition of Steam

16. In industry, ethanol is made by reacting ethene with steam in the presence of H₃PO₄.

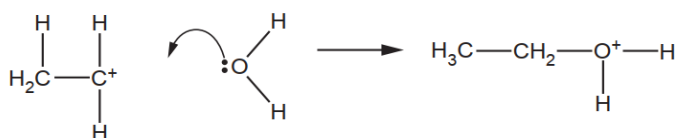
reaction 1 C₂H₄(g) + H₂O(g) ⇌ C₂H₅OH(g)

The mechanism for reaction 1 can be described in three steps. Steps 1 and 2 for reaction 1 are shown in the following figure.

step 1



step 2



(i) Describe the behaviour of H₃PO₄ in step 1. Explain your answer.

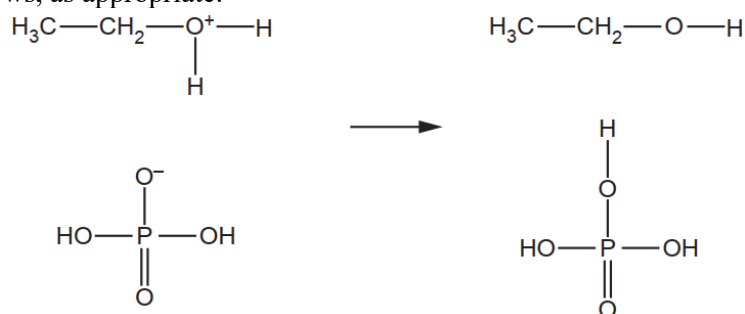
[1]

(ii) Identify the species that behaves as an electrophile in step 2. Explain your answer.

[1]

(iii) Complete Fig. 4.2 to show the mechanism for step 3 of reaction 1. Include charges, dipoles, lone pairs of electrons and curly arrows, as appropriate.

[2]



(iv) Use above mechanism steps to justify why H_3PO_4 is described as a catalyst in reaction 1.

[1]

(v) Propene also reacts with steam. A mixture of organic products is produced. Explain why propan-2-ol is produced in the higher yield.

17. Propene, C_3H_6 , reacts with H_2O in the presence of an acid catalyst to form an alcohol with molecular formula $\text{C}_3\text{H}_8\text{O}$.

(a) Name this type of reaction.

[1]

(b) Name the catalyst used and state the conditions needed for this reaction to occur.

[2]

(c) Complete the table to show the numbers of sigma (σ) bonds and pi (π) bonds present in propene, C_3H_6 , and $\text{C}_3\text{H}_8\text{O}$.

[2]

	σ	π
C_3H_6		
$\text{C}_3\text{H}_8\text{O}$		

(d) The reaction of propene, C_3H_6 , with H_2O occurs in a two-step mechanism. In step 1 C_3H_6 reacts with the catalyst, H^+ , to form a carbocation.

(i) Draw structures to identify the more stable and less stable carbocations which can form in step 1. Explain your answer.

[3]

(ii) Name the major organic product formed from the reaction of propene, C_3H_6 , with H_2O .

48. The conversion of propan-1-ol into propan-2-ol can be completed in a two-stage synthesis. The first stage is to heat the propan-1-ol with concentrated sulfuric acid. Which reagent would be needed to complete the second stage?

A cold dilute acidified manganate VII ions
B hot concentrated acidified manganate VII ions
C steam with phosphoric acid
D aqueous sodium hydroxide

18. But-1-ene reacts with steam in the presence of concentrated phosphoric acid to form two isomers of molecular formula $C_4H_{10}O$. Each reaction occurs via a different intermediate ion.

(i) Draw the structure of both intermediate ions.

[2]

(ii) Circle the more stable intermediate ion drawn in (i). Explain your answer.

[2]

19. Below is a list of species which can react with organic compounds.

CN^- HCl Cl^- H_2O CO_3^{2-}

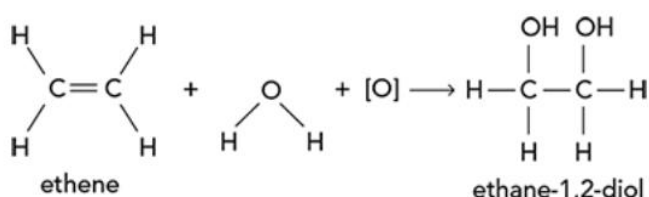
From the list, identify two species which can attack the π bond in ethene.

[1]

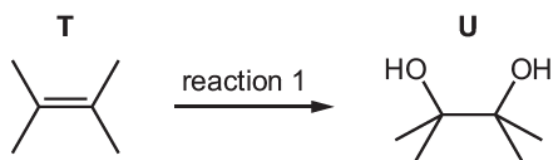
Oxidation

(a) by cold dilute acidified $KMnO_4$ to form the diol

If an alkene is shaken with a dilute solution of acidified potassium manganate(VII), $KMnO_4(aq)$, at room temperature, the pale purple solution turns colourless. The alkene is converted into a diol, i.e. a compound with two alcohol ($O-H$) groups:



20. A reaction scheme starting with **T** is shown.



Give the reagent(s) and conditions for reaction 1.

[1]

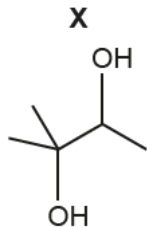
21. **V** reacts to form **Z** in a single reaction, as shown in the following figure.



(i) Suggest the reagent and conditions needed to form **Z** from **V**.

[1]

22. Compound **X** forms when methylbut-2-ene reacts with KMnO_4 .



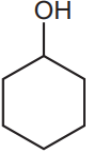
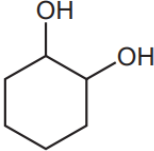
State the essential conditions for this reaction.

[1]

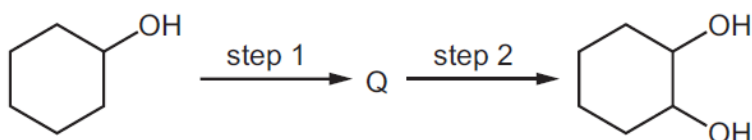
49. An alkene is reacted with acidified manganate(VII) ions, MnO_4^- . The organic product has a relative molecular mass greater than that of the alkene by 34.
What conditions should be used?

- A** cold, concentrated MnO_4^-
- B** cold, dilute MnO_4^-
- C** hot, concentrated MnO_4^-
- D** hot, dilute MnO_4^-

50. Which two-step process converts cyclohexanol into cyclohexane-1,2-diol?

	cyclohexanol	cyclohexane-1,2-diol
		
	→	
	step 1	step 2
A	heat strongly with Al_2O_3	add cold dilute $KMnO_4$ and H_2SO_4
B	heat strongly with Al_2O_3	heat with steam and H_2SO_4
C	reflux with ethanolic NaOH	add cold dilute $KMnO_4$ and H_2SO_4
D	reflux with ethanolic NaOH	heat with steam and H_2SO_4

1. Cyclohexanol is converted to cyclohexane-1,2-diol via a two-step synthesis that proceeds via intermediate Q.



Which row identifies the type of reaction in step 1 and in step 2?

	step 1	step 2
A	dehydration	oxidation
B	dehydration	nucleophilic substitution
C	Reduction	oxidation
D	Reduction	nucleophilic substitution

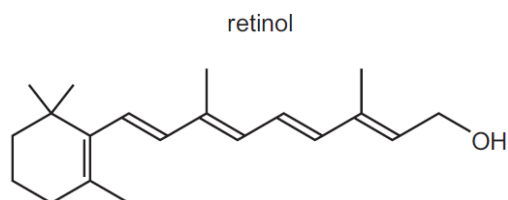
(b) by hot concentrated acidified $KMnO_4$

Under these harsher conditions, the $C=C$ double bond in the alkene is broken completely. The $O-H$ groups in the diol formed initially are further oxidised to ketones, aldehydes, carboxylic acids or carbon dioxide gas. The actual products depend on what is bonded to the carbon atoms in the $C=C$ double bond.

2. 2-methylbut-2-ene is reacted with hot, concentrated, acidified potassium manganate (VII) solution. What are the products of this reaction?

- A ethanal and propanone
- B ethanoic acid and propanone
- C ethanoic acid and propan-2-ol
- D ethanol and propan-2-ol

3. Vitamin A contains retinol.



Under appropriate conditions, acidified $\text{KMnO}_4(\text{aq})$ can be used to break $\text{C}=\text{C}$ bonds.

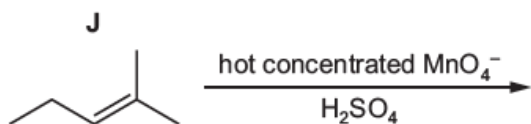
After these bonds have been broken, further oxidation of the fragments may occur.

Under which conditions is the acidified $\text{KMnO}_4(\text{aq})$ used and what do the final oxidation products include?

	conditions	final oxidation products
A	cold, dilute	aldehydes and carboxylic acids
B	cold, dilute	ketones and carboxylic acids
C	hot, concentrated	aldehydes and carboxylic acids
D	hot, concentrated	ketones and carboxylic acids

23. Identify the organic products formed when compound **J**, shown below, is heated with hot concentrated acidified manganate (VII) ions.

[2]



24. Hex-3-ene is an isomer of cyclohexane. Hex-3-ene can be converted into propanoic acid.

reaction 3

hex-3-ene $\longrightarrow$ propanoic acid

Deduce the reagents and conditions for reaction 3.

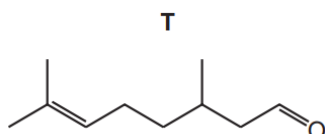
[2]

4. P and Q are alkenes. They are geometric isomers of each other.
Which statement is correct?

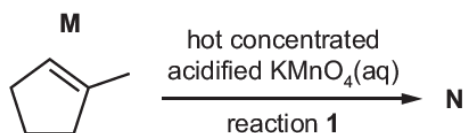
A	P and Q give different products with hot, concentrated, acidified potassium manganate (VII).
B	P and Q have different empirical formulae.
C	P and Q have different functional groups.
D	P and Q have different skeletal formulae.

25. Two organic products are produced when a sample of **T** is heated under reflux with excess acidified concentrated KMnO_4 .

Draw the structure of the two organic products, from this reaction.



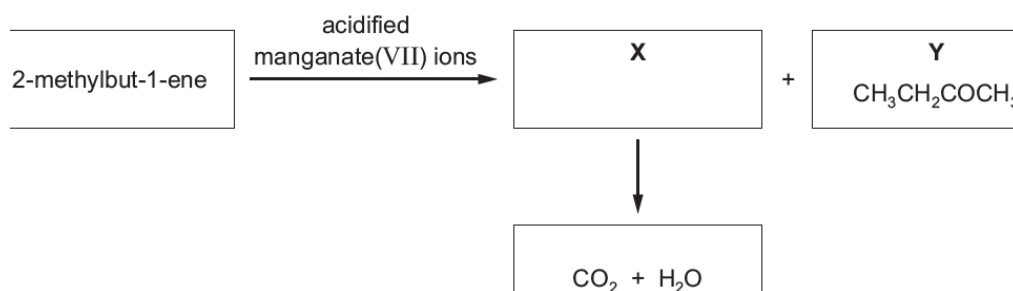
26. **M** reacts with hot concentrated acidified $\text{KMnO}_4(\text{aq})$ to form **N**, $\text{C}_6\text{H}_{10}\text{O}_3$, in reaction 1.



Draw the structure of **N**.

[1]

27. 2-methylbut-1-ene reacts with acidified manganate(VII) ions, under specific conditions, to produce two organic compounds **X** and **Y**.



X immediately reacts with the acidified manganate(VII) ions to form carbon dioxide and water. **Y** has the structural formula $\text{CH}_3\text{CH}_2\text{COCH}_3$.

(i) State the specific conditions required for the acidified manganate(VII) ions to react with 2-methylbut-1-ene in this way. [1]

(ii) Name the type of reaction occurring to the functional group in 2-methylbut-1-ene in the reaction in (i). [1]

(iii) Draw the structural formula of **X**. [1]

28. When propene reacts with CO and an excess of H_2 , an alkane and a mixture of alcohols are formed instead. The alcohols are isomers of each other.
Suggest the molecular formulae of the alkane and the alcohols that are formed under these conditions. [2]

5. Which substance forms propanoic acid as one of the products when it reacts with hot concentrated acidified potassium manganate(VII)?

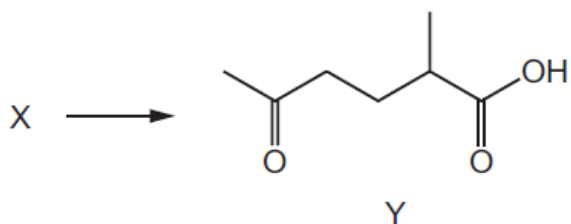
A but-1-ene

B but-2-ene

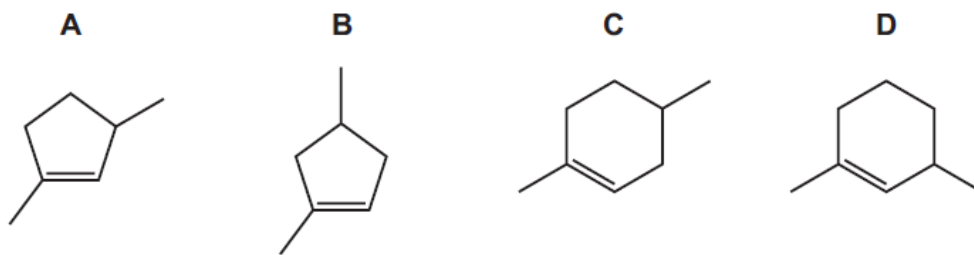
C 2-methylpropene

D 2-methylbut-1-ene

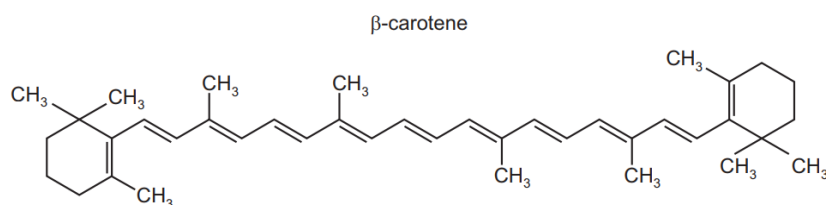
6. Compound X can be converted into compound Y in a single step.



What could be the identity of X?



7. β -carotene is responsible for the orange colour of carrots.



β -carotene is oxidised by hot, concentrated, acidified KMnO_4 .

When an individual molecule of β -carotene is oxidised in this way, many product molecules are formed. How many of these product molecules contain a ketone functional group?

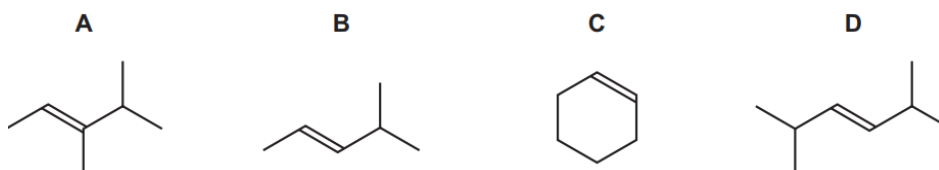
A 4

B 6

C 9

D 11

8. Which compound would produce two different carboxylic acids when treated with hot, concentrated, acidified manganate(VII) ions?



9. But-1-ene and but-2-ene are treated separately with cold, dilute acidified manganate(VII) ions. Four students, W, X, Y and Z, make statements about these alkenes and the diols formed from them.

W One diol contains two primary alcohol groups.

X One diol contains a primary and a secondary alcohol group.

Y One diol contains two secondary alcohol groups.

Z Both alkenes exhibit cis-trans isomerism.

Which two students are correct?

A W and Y

B W and Z

C X and Y

D X and Z

10. The table describes four reactions of propene. Which row is correct?

	reagent used	name of main organic product
A	aqueous bromine	2-bromopropane
B	cold acidified aqueous potassium manganate(VII)	propane-1,3-diol
C	hydrogen chloride	2-chloropropane
D	steam	propan-1-ol

11. Which feature is present in both ethene and poly(ethene)?

A bond angles of 109.5°

B covalent bonds

C σ covalent bonds

D sp^3 orbitals

29. Fig. 3.2 shows a reaction cycle involving cyclopentane, cyclopentene and C_5H_9Cl .

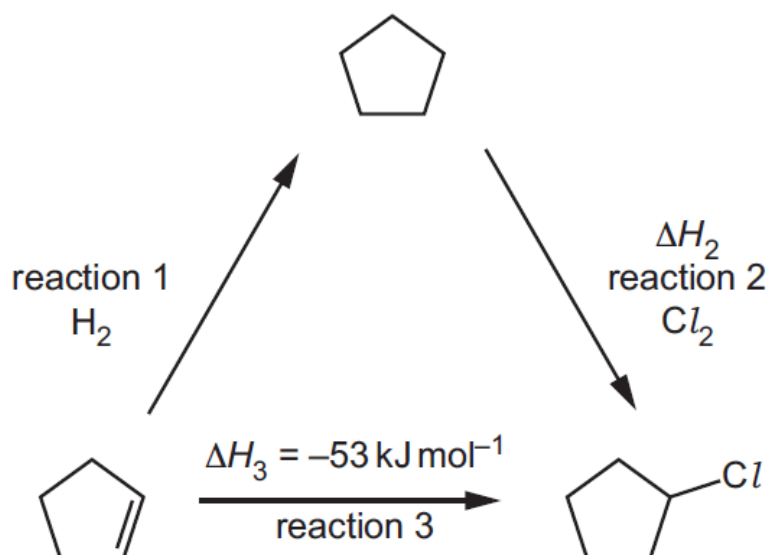


Fig. 3.2

- (i) Identify a suitable reagent for reaction 3.

..... [1]

(ii) Use the data in Fig. 3.2 and in Table 3.1 to calculate the enthalpy change of reaction 2, ΔH_2 .

Table 3.1

compound	enthalpy change of combustion, $\Delta H_c / \text{kJ mol}^{-1}$
	-3292
	-3115
H_2	-286

30. Compounds P and Q are structural isomers.



(iii) Both P and Q react with aqueous bromine.

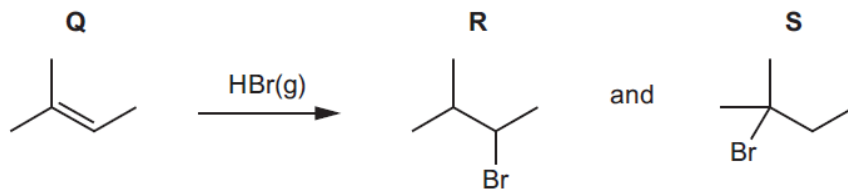
Name the mechanism of this reaction.

..... [1]

(iv) Q is oxidised by hot concentrated acidified $\text{KMnO}_4(\text{aq})$, forming two different organic products. Construct an equation for this reaction. Use [O] to represent an atom of oxygen from the oxidising agent.

$(\text{CH}_3)_2\text{C}=\text{CHCH}_3$ [2]

31. Q reacts with $\text{HBr}(\text{g})$ to produce two structural isomers, R and S, as shown in Fig. 4.2.



State and explain why isomer S is the major product of the reaction.

.....

 [2]